Notice of Allowability	Application No.	Applicant(s)	
	10/722,385	POLETTI, MARK	
	Examiner	Art Unit	
	Xu Mei	2644	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *amendment dated 9/21/2004*.

2. ☒ The allowed claim(s) is/are *4-7*.

3. ☒ The drawings filed on *25 November 2003* are accepted by the Examiner.

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO-1449 or PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application (PTO-152)
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

Xu Mei
Primary Examiner
Art Unit: 2644

1. An Examiner's Amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 C.F.R. § 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the Issue Fee.

2. Authorization for this Examiner's Amendment was given in a telephone interview with Mr. Clifford Browning (Reg. No. 32201) on 08/02/05.

3. In the Specification:

Please providing the following changes to the specification **without** underlining and bracketing:

At column 5, line 61 (equation 16), please delete "$V_+(z)=U(z)-GD(z)V_+(z)$" and insert in lieu thereof -- $V_+(z)=U(z)-\mu GD(z)V_+(z)$ --.

At column 5, line 65 (equation 17), please delete "$D(z)=diag[z^{-L1}, z^{-L1}...z^{-LN}$" and insert in lieu thereof -- $D(z)=diag[z^{-L1}, z^{-L2}, ...z^{-LN}$--.

At column 6, line 52 (equation 26), please delete "$=QA \cdot AQ^+$" and insert in lieu thereof -- $=QA * AQ^+$ --.

4. In the Claims:

The following amendment is to correct the minor typographical errors on dependent claims 5-6:

Claims 5-6, line 2, "claim 1" has been replaced with -- claim 4--; since claims 5-6 should be depending on independent claim 4 instead of canceled claim 1.

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5. Any comments considered necessary by applicant must be submitted no later than the payment of the Issue Fee and, to avoid processing delays, should preferably accompany the Issue Fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Xu Mei whose telephone number is 571-272-7523. The examiner can normally be reached on Monday-Friday (9:30-6:00).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Vivian Chin can be reached on 571-272-7848. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Xu Mei
Primary Examiner
Art Unit 2644
08/03/2005

$$y(n)^T y(n) = u^T X^T X u = u^T u = N \quad (10)$$

where the time dependence cancels. Thus the output power is equal to N for constant sinusoidal excitation and is independent of the input phases. The power gain is thus unity at all frequencies. Hence: A linear multichannel system may be termed unitary if its transfer function matrix is unitary at all frequencies. A unitary system has a constant norm and unit power gain for all frequencies.

A unitary system is ideal for use in the VRA system since it has the same power gain at all frequencies and thus will not increase the colouration. It may also be inserted into an MCR system without altering the loop gain. The power gain of the VRA system with a unitary reverberator is given by

$$P_{VRA|unitary} = \frac{1}{1-\alpha_{VRA}^2 N} \quad (11)$$

which equals P_{MCR} for $\alpha_{VRA}=\alpha_{MCR}$.

Most digital reverberators are based on the comb filter, shown in FIG. 2 [8–10]. This circuit produces an impulse response that is an exponentially decaying sequence of delta functions occuring at multiples of the delay time $\tau=L/f_s$ where f_s is the sample rate. The output may be taken from the summer, the delay or the multiplier outputs. The transfer function for the comb filter with output taken from the delay output is

$$X(z) = \frac{z^{-L}}{1+\mu z^{-L}} \quad (12)$$

The single channel comb filter can be made to have a constant magnitude verses frequency response (termed an allpass response) by incorporating a feedforward section into the circuit. An efficient one multiplier form of the allpass form is shown in FIG. 3 [8,9]. The transfer function is given by

$$X(z) = \frac{\mu+z^{-L}}{1+\mu z^{-L}} \quad (13)$$

The magnitude squared at $z=\exp(j\theta)$ is

$$|X(e^{j\theta})|^2 = \frac{1+\mu^2+2\cos(L\theta)}{1+\mu^2+2\cos(L\theta)} \quad (14)$$

which is unity, as required.

Early forms of reverberator were constructed using a number of comb filters in parallel, with the summed outputs being fed into a number of allpass sections to increase the echo density [8]. A more recent structure for multichannel reverberators is as shown in FIG. 4 [9,10]. This structure is an extension of the single channel comb filter which achieves a high echo density by the cross coupling of a number of single channel comb filters, via the cross coupling matrix G. Subsequent allpass sections are not required. The response of the vector comb filter may be determined by assuming that the input is a vector of discrete signals $u_i(n)$ with a vector spectrum

$$U(z)=[U_1(z),U_2(z),\ldots,U_M(z)]^T \quad (15)$$

The vector spectrum at the output of the adders is given by

$$V_+(z) = U(z) - \mu G D(z) V_+(z) \quad (16)$$

where D(z) is a diagonal delay matrix

$$D(z) = \mathrm{diag}[z^{-L_1}, z^{-L_2}, \ldots, z^{-L_N}] \quad (17)$$

Solving for $V_+(z)$ allows the output vector spectrum V(z) to be found;

$$V(z)=D(Z)[I+\mu GD(z)]^{-1}U(z) \quad (18)$$

It can be shown [9, 10] that if the gain matrix G is orthonormal, ie $G^TG=I$, then the system is stable for $\mu<1$. The poles of the system are distributed in the z plane around a circle with radius less than unity.

The multichannel reverberator circuit can be made to have allpass properties if a feedforward section is incorporated into the circuit, as in the one dimensional case. An efficient form with a single vector gain element (μ) and single cross coupling matrix G, is shown in FIG. 5. The output vector spectrum is given by

$$V(z)=[\mu I+GD(z)][I+\mu GD(z)]^{-1}U(z) \quad (19)$$

The order of the gain and delay matrices may be reversed without altering the allpass properties of the circuit. It may be verified that the transfer function matrix in equation 19 is unitary at all frequencies as follows:

At any given frequency ω, the matrix transfer function has the form

$$X=[\mu I+GD][I+\mu GD]^{-1} \quad (20)$$

where $D=\mathrm{diag}[\exp(j\phi_1),\exp(j\phi_2),\ldots,\exp(j\phi_N)]$. Now, the product GD is a unitary matrix since

$$(GD)^T(GD)=D^TG^TGD=I \quad (21)$$

The eigenvalues decomposition of GD is thus

$$GD=QAQ^T \quad (22)$$

where Q is a unitary matrix and Λ is a diagonal matrix of eigenvalues. Since GD is unitary the eigenvalues have unit magnitude, ie

$$\Lambda=\mathrm{diag}[e^{j\phi_1}, e^{j\phi_2}, \ldots, e^{j\phi_N}] \quad (23)$$

X may now be written

$$\begin{aligned} X &= [\mu I + Q\Lambda Q^T][I+\mu Q\Lambda Q^T]^{-1} \quad (24)\\ &= [Q(\mu I+\Lambda)Q^T][Q(I+\mu\Lambda)Q^T]^{-1}\\ &= Q(\mu I+\Lambda)Q^TQ(I+\mu\Lambda)^{-1}Q^T\\ &= Q(\mu I+\Lambda)(I+\mu\Lambda)^{-1}Q^T\\ &= QAQ^T \end{aligned}$$

where A has the diagonal allpass form

$$A = \mathrm{diag}\left[\frac{\mu+e^{j\phi_1}}{1+\mu e^{j\phi_1}}, \frac{\mu+e^{j\phi_2}}{1+\mu e^{j\phi_2}}, \ldots \frac{\mu+e^{j\phi_N}}{1+\mu e^{j\phi_N}}\right]. \quad (25)$$

We can now write

$$\begin{aligned} X^TX &= QA^TQ^TQAQ^T \quad (26)\\ &= QA^*AQ^T \quad = QA*AQ^T\\ &= I \end{aligned}$$

Hence the transfer function matrix X is unitary at all frequencies. The unitary system is formed from a set of N independent single dimensional allpass filters with a pre-coupling matrix $Q^T(\omega)$ and a post coupling matrix $Q(\omega)$.

The foregoing describes the invention including preferred forms thereof. Alterations and modifications as will be obvious to those skilled in the art are intended to be incorporated in the scope hereof.

References

1) P. H. Parkin and K. Morgan, "Assisted Resonance in the Royal Festival Hall," *J. Acoust. Soc. Amer.*, vol. 48, pp 1025–1035, 1970